Understanding Haddock somatic growth changes on Eastern Georges Bank

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Part 1. Modelling haddock growth changes

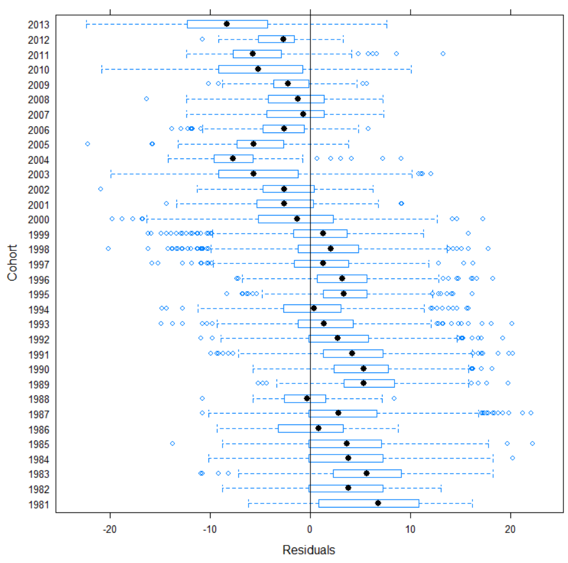
Haddock length data

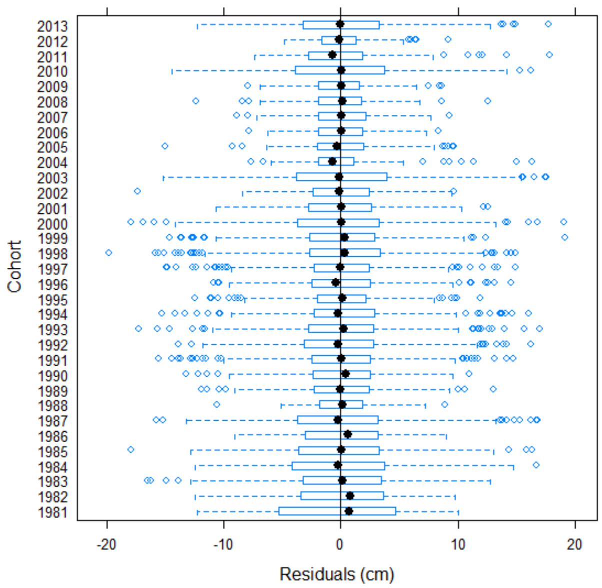
- EGB haddock length at age from 1986-2017 using DFO survey samples
- Ages 1-8

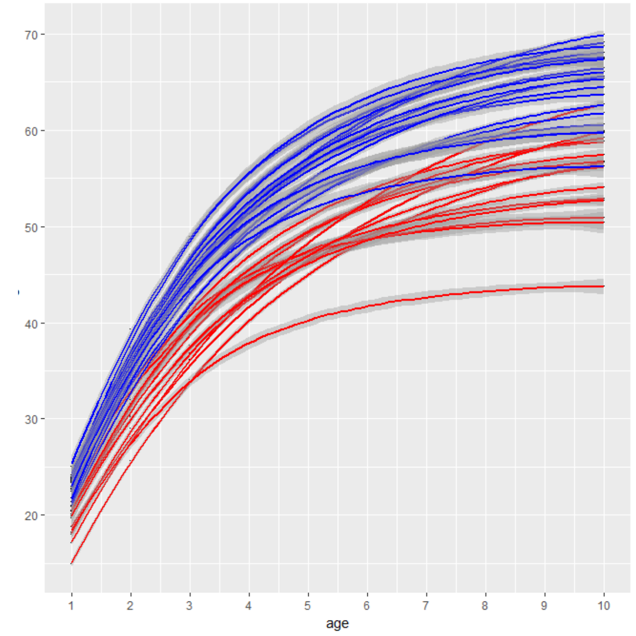
Von Bertlanffy Mixed effect model

La~Linf*(1-exp(-1*K*(Age-t0)))

Von Bertlanffy Model



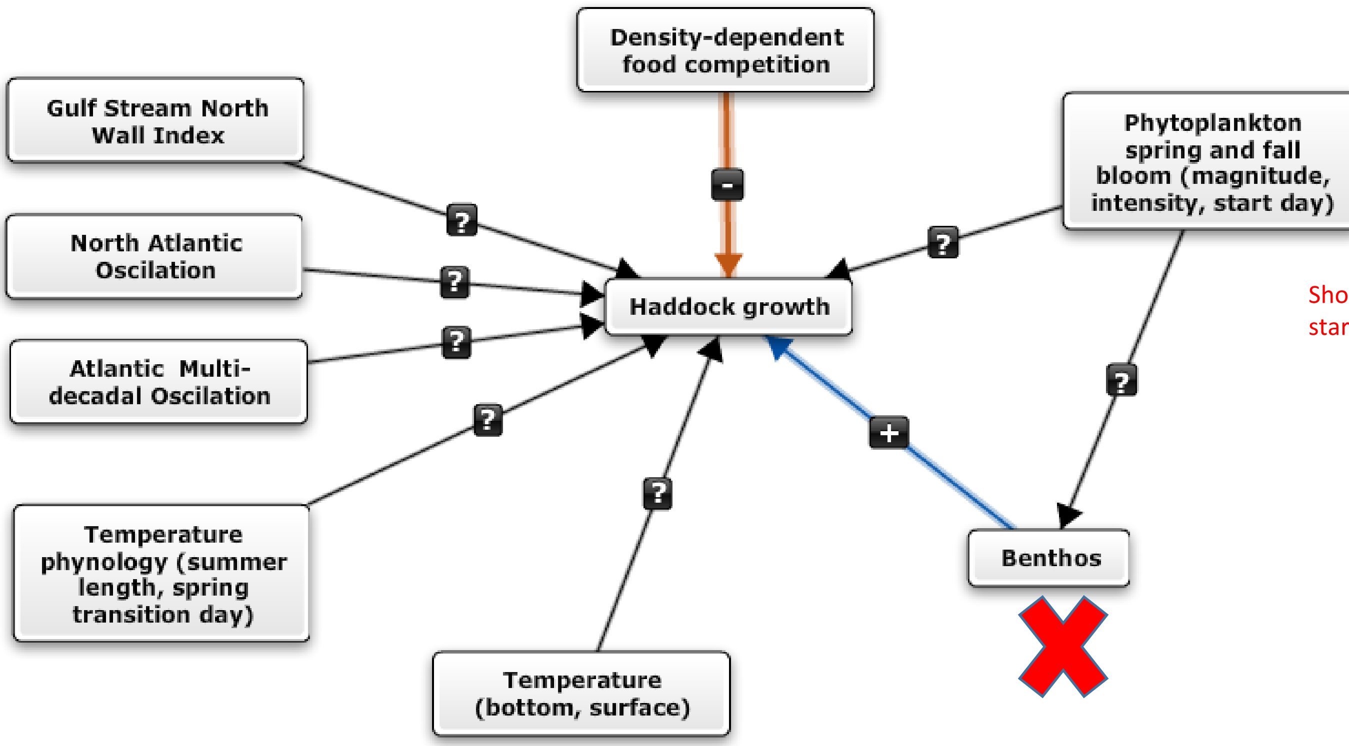




Part 2.

Understanding the mechanism of somatic growth changes of Eastern Georges Bank haddock

Conceptual model: possible relevant factors to haddock growth



Short time series starting 1998

Fish Density

- *Cohort strength*:

$$\ln A_{ijs} = \beta_i + \beta_j + \beta_s + \beta_{is} + \epsilon$$

where A_{ijk} is the survey index at age i, $i = 1, 2$, and cohort j, $j = 1985, 1986, \dots, 2015$, in survey s

- *Annual biomass*:

$$\ln B_{ts} = \ \beta_t + \beta_s + \epsilon$$

where B_{ts} is the survey biomass index in year t, $t = 1987, \dots, 2017$ from survey s

GAM model

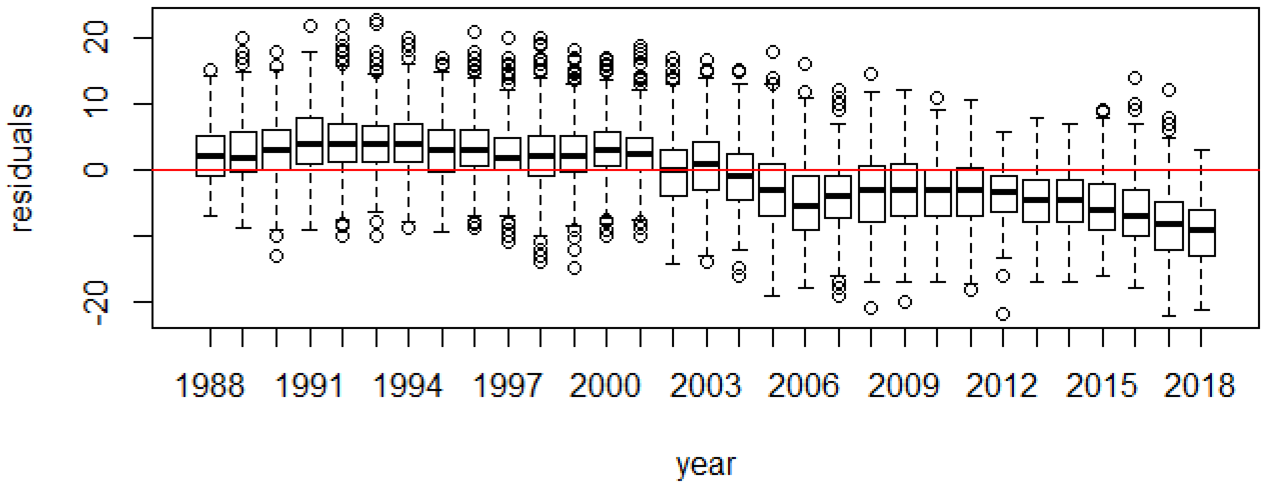
For both long(1987-2018) and short(1998-2018) time series data:

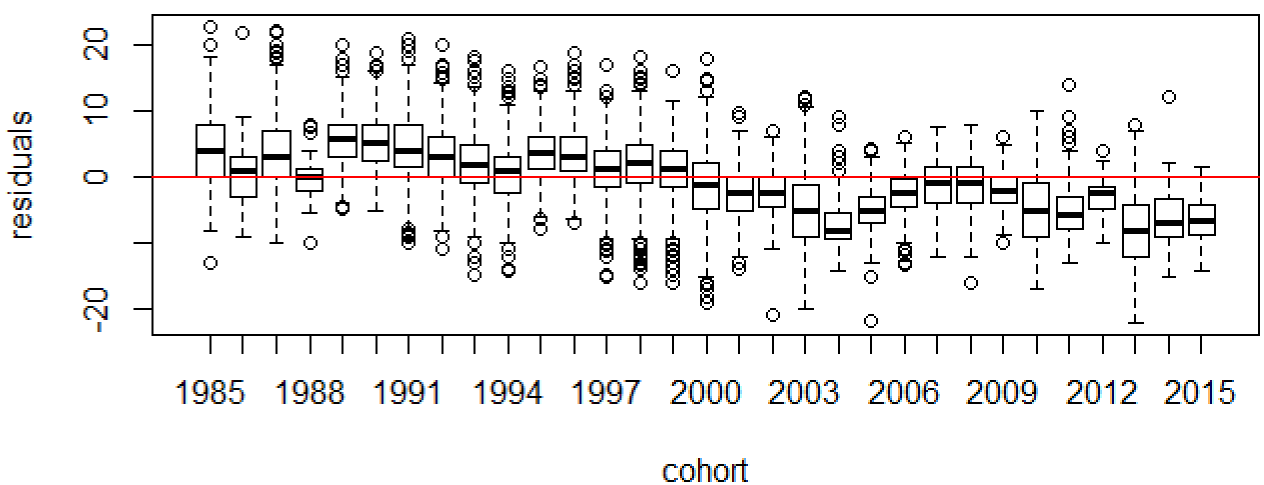
- *Step 1:* GAM model to relate Length with Age

$$La \sim s(age)+\epsilon \quad \epsilon \sim N(0,1)$$

- *Step 2:* GAM model to interpret the impact of environmental factors on the variation of haddock growth.
  - Response variable: residuals (ϵ) from step 1.
  - Predictor variables: variables in the conceptual model except for benthos data

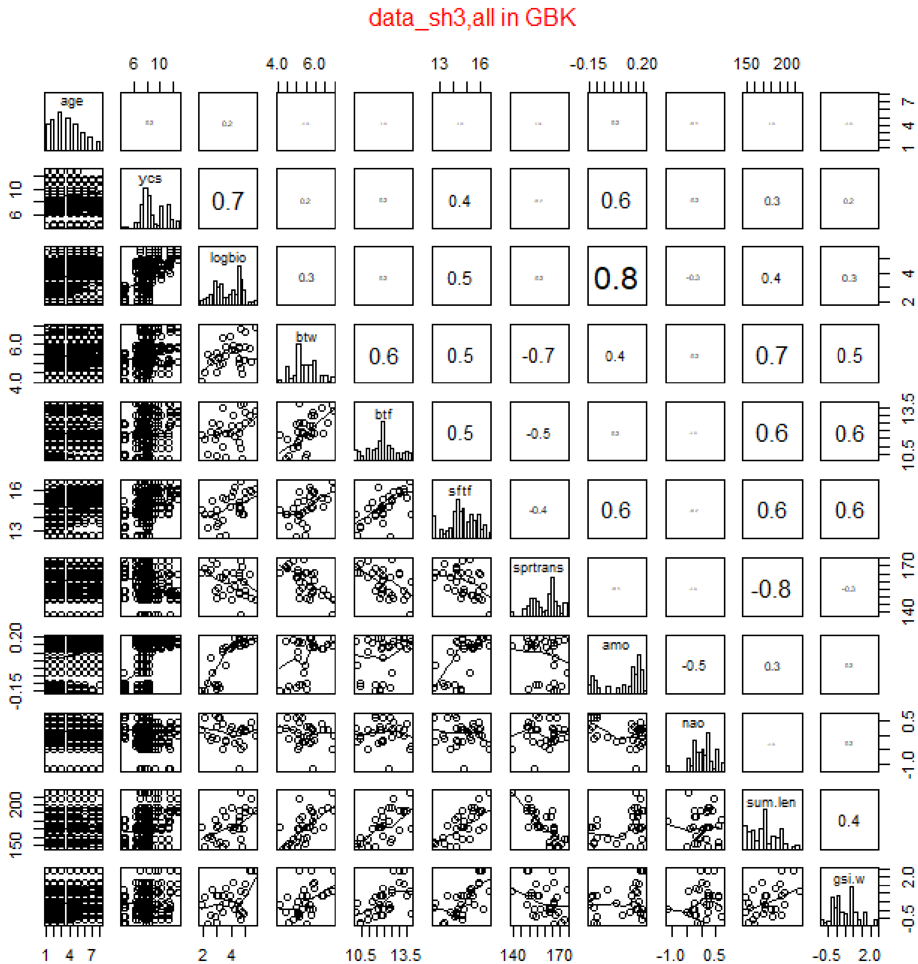
Long time series data





La ~ s(age)+ϵ

Collinearity check



- Covariate variables with the variance inflation factor (VIF>3) and linear correlation $r^2>0.7$

GAM models

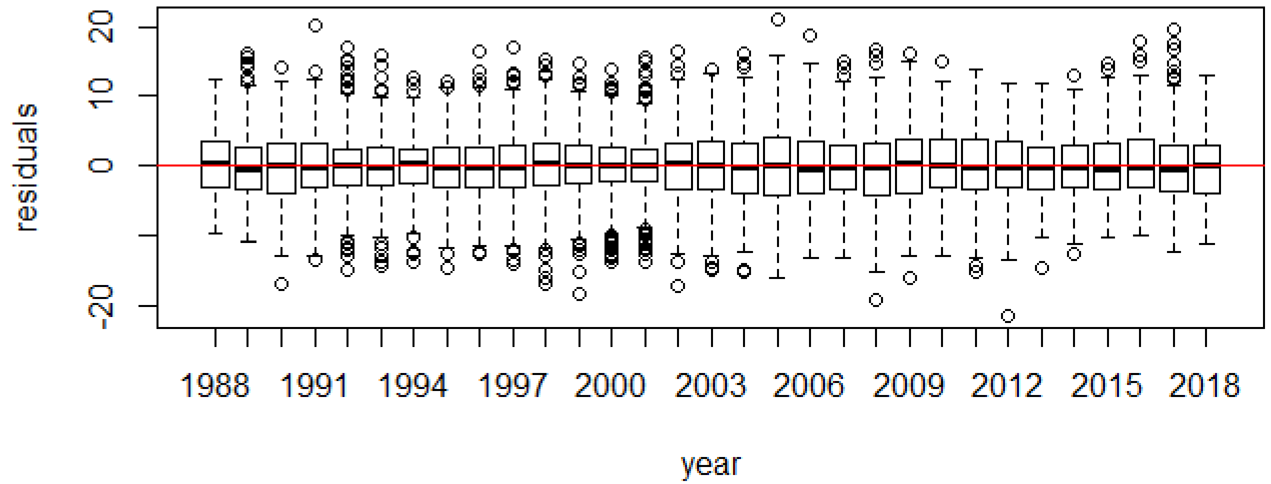
- **Smooth parameter estimation and variable selection**: Double penalty(Marra and Wood,2011) smooth approach.

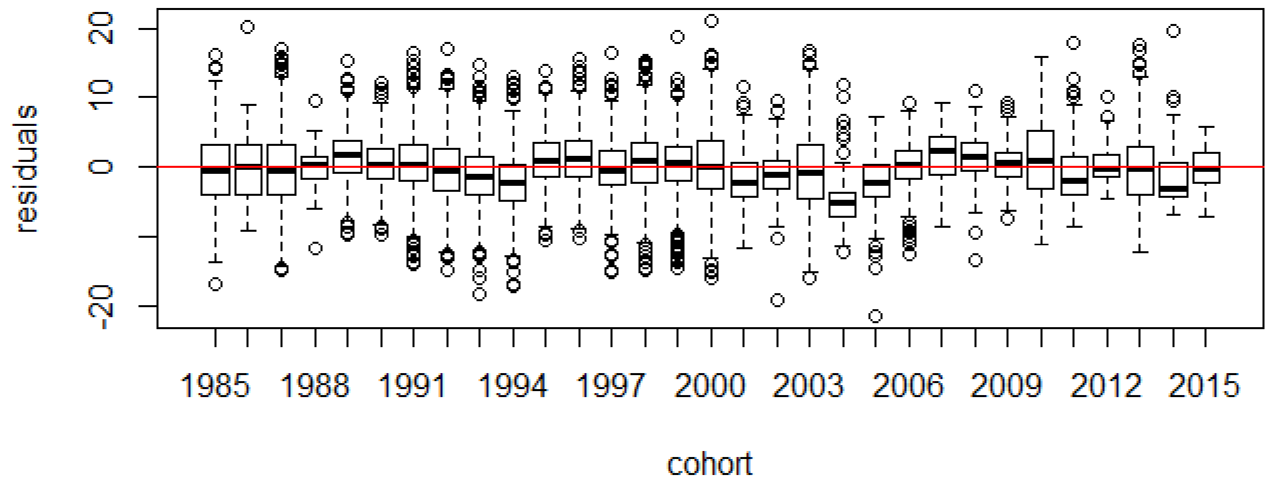
- ***Model selection****: based on AIC and anova test*

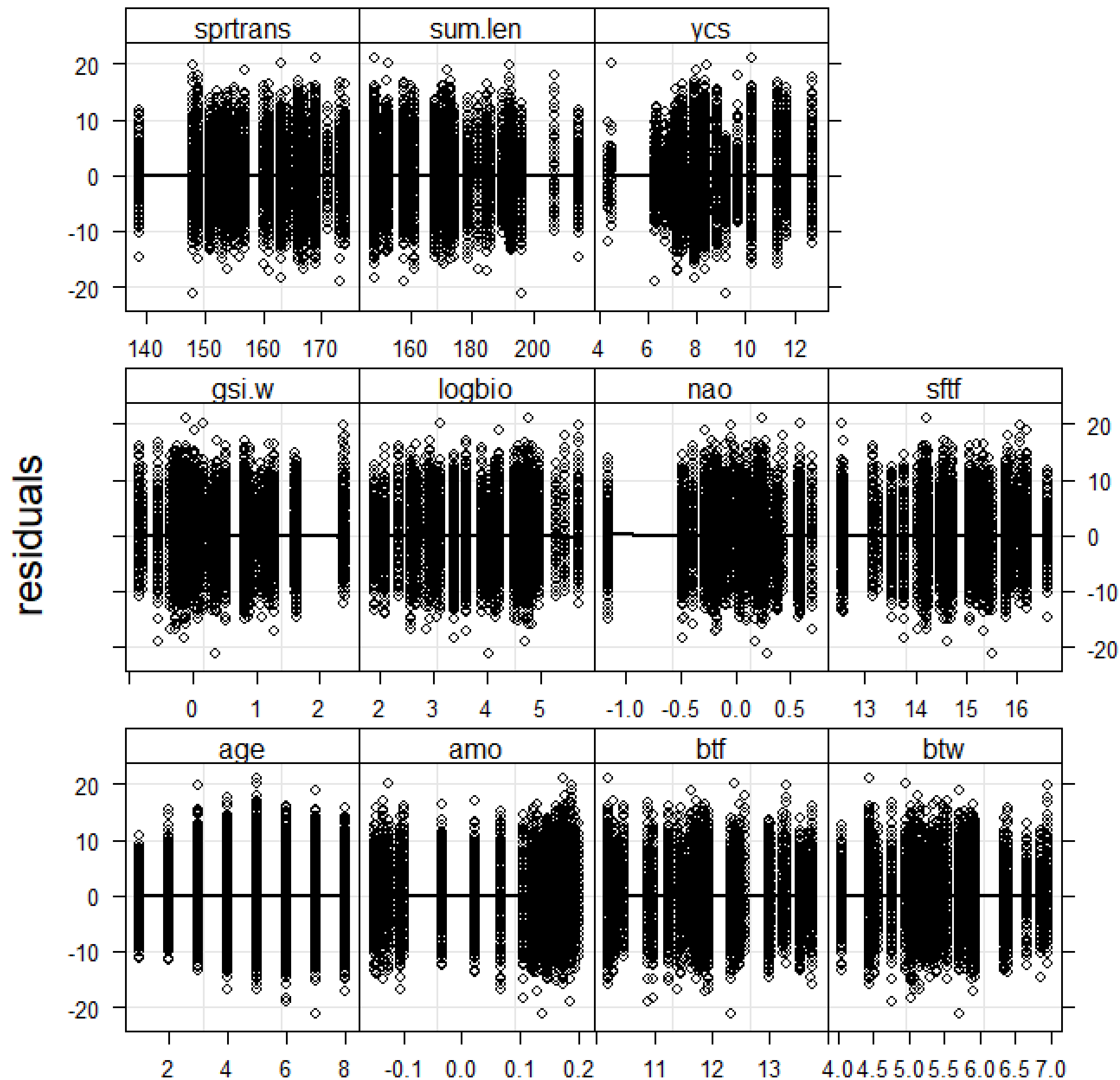
  - ϵ ~ s(ycs)+s(bio)+s(btf)+s(sftf)+s(sprtrans)+s(nao)+s(gsi.w)
  - ϵ ~ s(ycs)+ s(bio)+ te(bio, age)+s(btf)+s(sftf)+s(sprtrans)+s(nao)+s(gsi.w)
  - ϵ ~ s(ycs)+s(bio, by=age)+s(btf)+s(sftf)+s(sprtrans)+s(nao)+s(gsi.w)

Model check

ϵ ~ s(ycs)+ s(bio)+ te(bio, age)+s(btf)+s(sftf)+s(sprtrans)+s(nao)+s(gsi.w)







sprtrans
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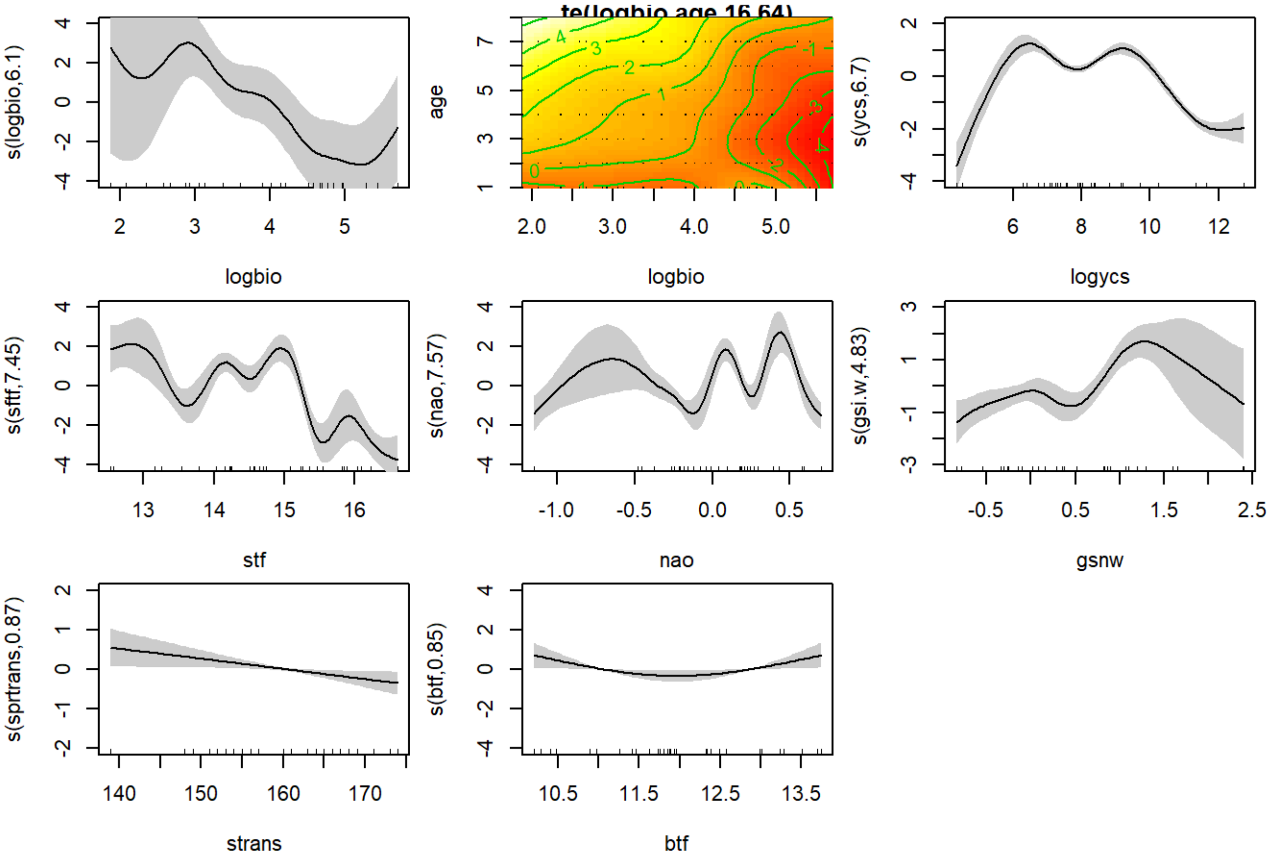
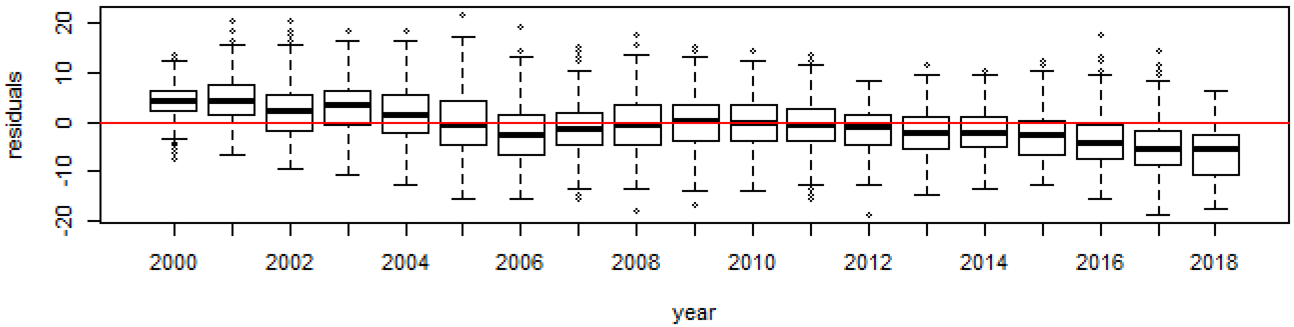
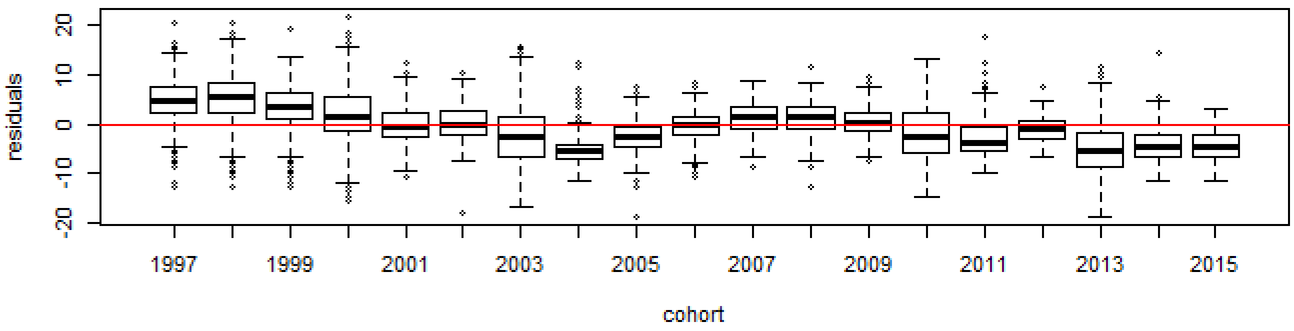


- Deviance explained 40.6%
- density-dependent effect explained 36.8% of deviance

short time series data(1998-2018)



La ~ s(age)+ϵ

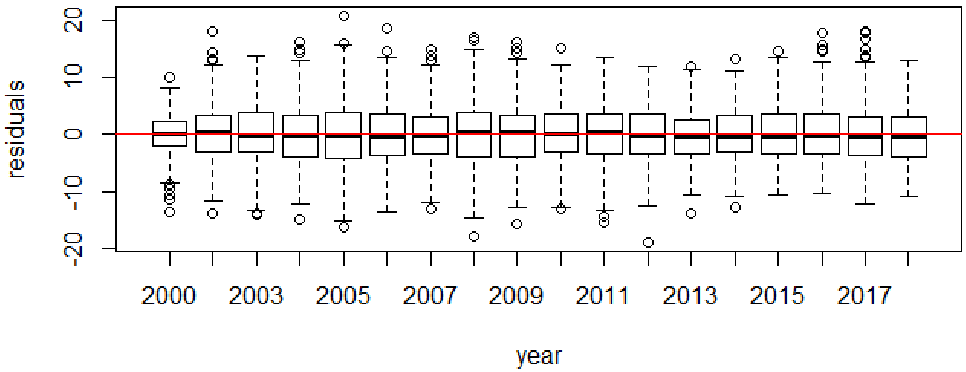


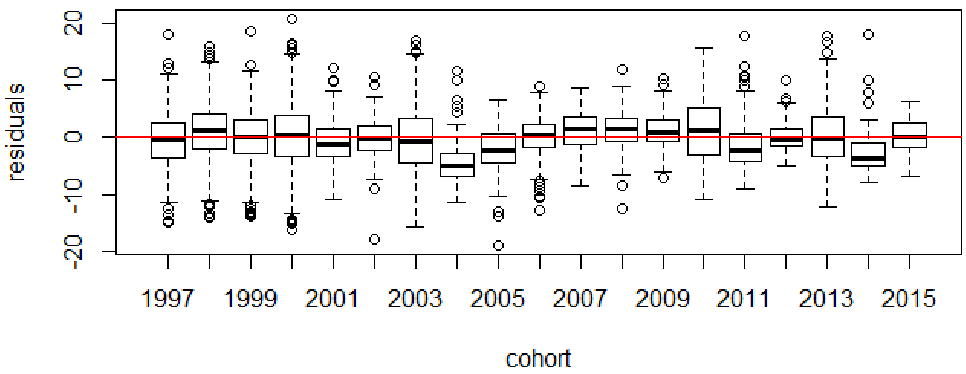
GAM models

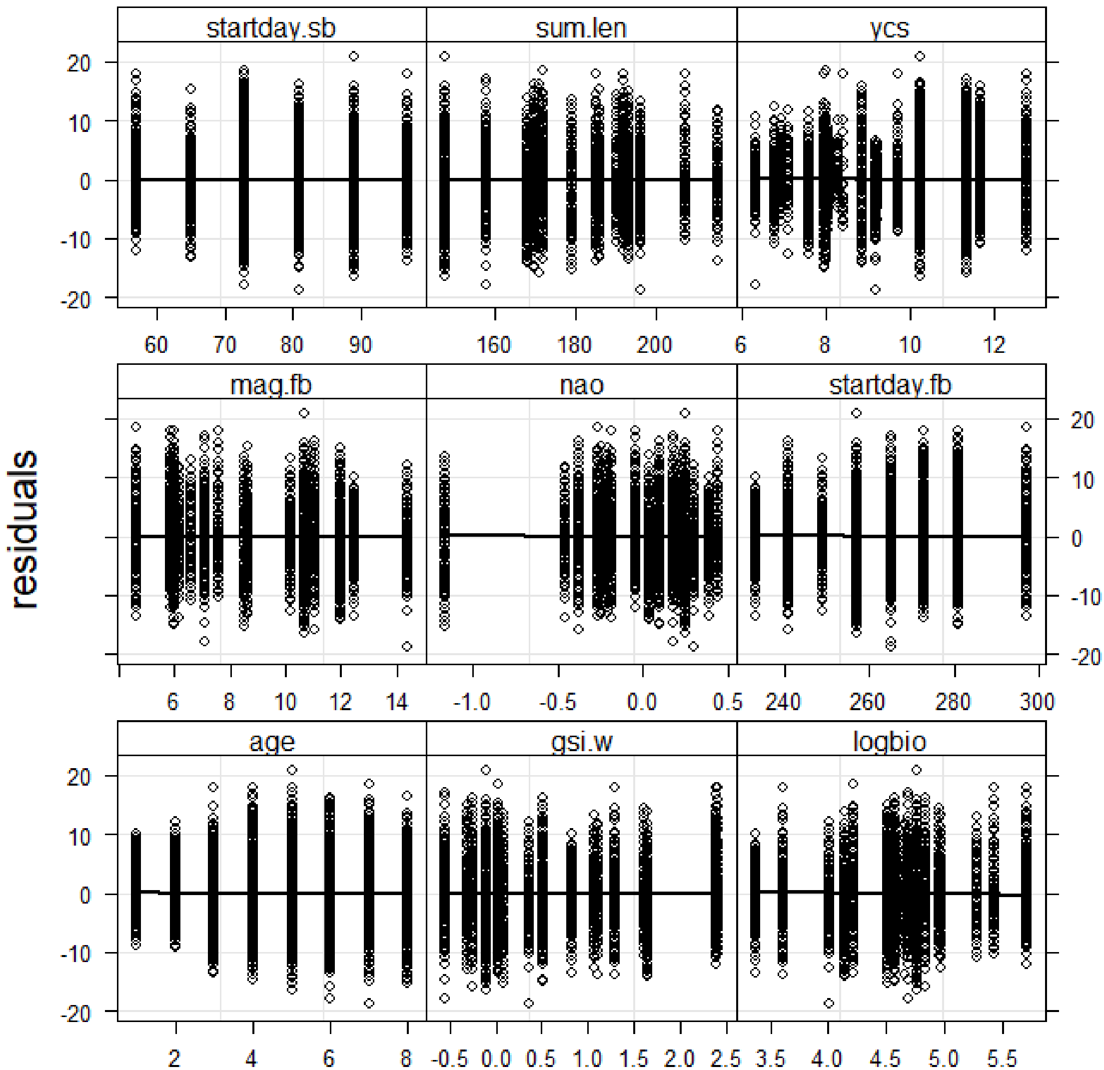
- ***Model selection**: based on AIC and anova test*
  - ϵ ~ s(ycs)+s(bio)+s(btf)+s(sftf)+s(sprtrans)+s(nao)+s(gsi.w)
  - ϵ ~ s(ycs)+ s(bio)+ te(bio, age)+s(btf)+s(sftf)+s(sprtrans)+s(nao)+s(gsi.w)
  - ϵ ~ s(ycs)+s(bio, by=age)+s(btf)+s(sftf)+s(sprtrans)+s(nao)+s(gsi.w)

Model check

$\epsilon \sim s(ycs) + te(bio, age) + s(nao) + s(mag.fb)$






residuals
startday.sb
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mag.fb
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startday.fb
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gsi.w
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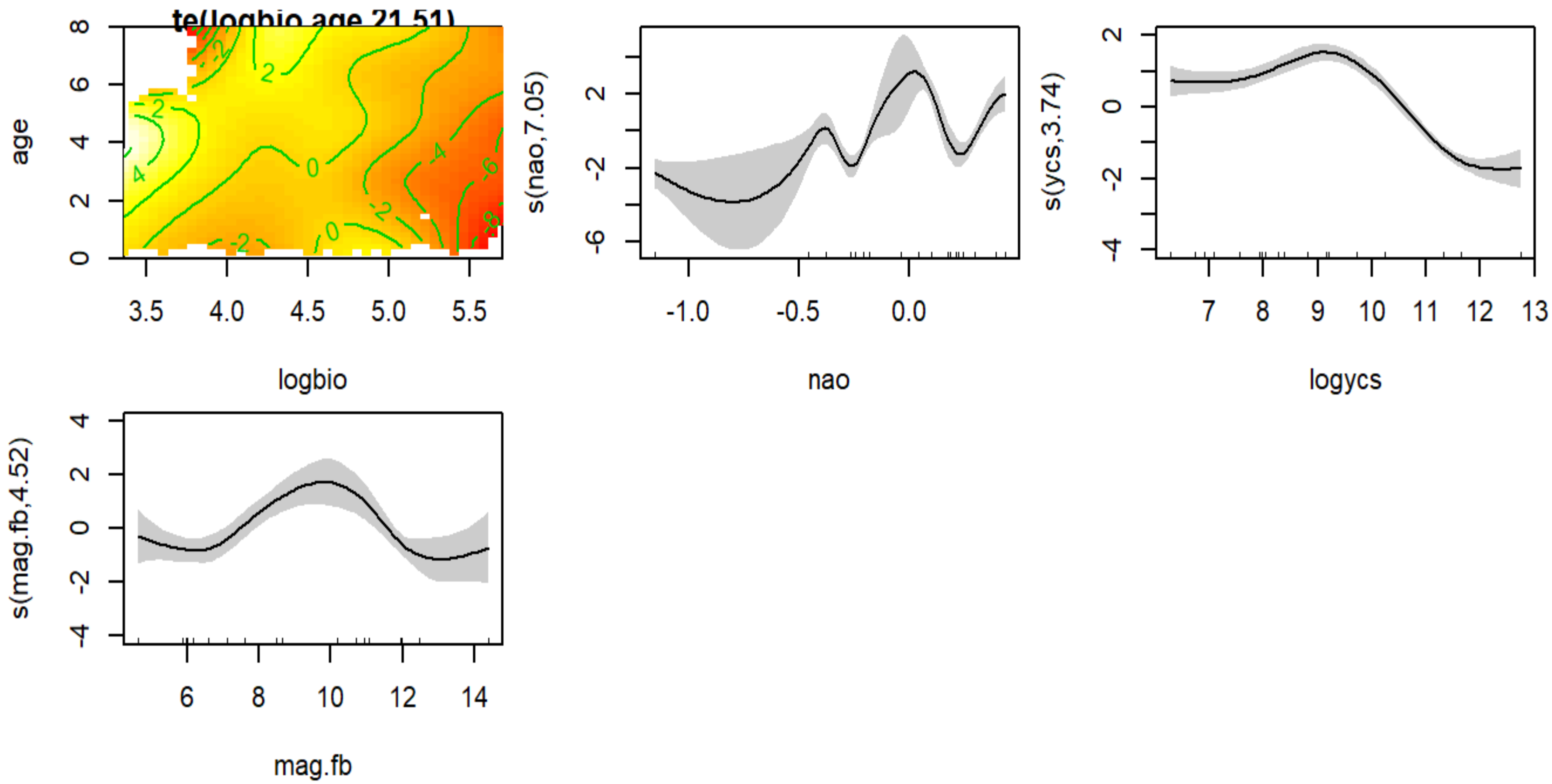

- Deviance explained 23.6%
- density-dependent effect explained 19.1% of deviance

summary

- Density dependent effect and possible high temp in the summer and fall have the most influences on haddock growth changes.

- Consistent with Clarks(1969) description about fish size reduction following very strong cohorts in the history.

- Care is needed with the interpretation of the very week cohorts at older ages due to small number of samples

- When there are high concurvity among covariate variables, accurately estimate these nonlinear effects could be tricky.